C.A.M. 5069

DEC 14 1981

UNIVERSITÉ DE MONTRÉAL
AOU
BIBLIOTHÈQUE

PUBLICATIONS
OF THE
Dominion Astrophysical Observatory
VICTORIA
Vol. 1, No. 4.

ORBIT OF THE SPECTROSCOPIC BINARY 1 GEMINORUM

BY REYNOLD K. YOUNG

1 Geminorum [α (1900) = $5^h\ 58^m.0$, δ + 23° 16′, vis. mag. = 4.30, type G5.] was announced as a spectroscopic binary in Lick Obs. Bul. Vol. IV, page 107. Four spectrograms were made at the Lick Observatory from 1903 to 1906. Three additional spectrograms were made at the Bonn Observatory from 1909 to 1912. The star was placed on the observing list at Ottawa in December of 1916 in the hope that the range might prove large enough to permit its orbit being obtained with one prism dispersion. Twenty-six plates were secured in the early months of 1917 but these did not seem sufficient to give accurate elements and it was therefore left to be finished from observations with the 72-inch reflector at Victoria.

The determination of the period has proved to be difficult. Fifty-one observations have been secured here and these are in harmony with a period of 9·590 days. This same period will satisfy the Ottawa observations in 1917 very well and the Bonn observations in 1909 and 1912. The residuals are somewhat larger than one would be led to expect from the fine quality of the spectrum but on the whole they indicate that the period 9·590 days is satisfactory. The Lick observations taken in 1903 to 1906 could not be made to agree and it would seem that there are peculiarities in the orbit not yet explained. The double amplitude of the curve is twenty-three kilometers only and the irregularities in the curve are of the order of five kilometers or a little over so that the complete investigation with one prism dispersion would prove a difficult task. Three prism dispersions would be much better but until such is available the present elements serve as a good approximation to give the general form of the curve.

In the table of observations, which follows, the plates taken at Ottawa were measured with the Toepfer measuring machine while the Victoria spectrograms were measured on the Hartmann comparator with a sky or α Bootis standard. Some of the plates were measured with both standards and seemed to give practically the same result.

TABLE OF OBSERVATIONS

Plate	Observer	Date			Julian Day	Velocity	Wt	Phase	O-C
Lick	..	1903	Jan.	4	2,416,119·78	+33·8	.....	0·52	
"	..	1905	Sept.	27	7,116·01	+19·8	.....	1·83	
"	..	1906	Oct.	1	7,485·04	+15·8	.....	6·44	
"	..	"	Nov.	9	7,524·98	+19·9	.....	8·02	
Bonn	..	1909	Jan.	22	8,329·43	+12·3	.....	6·91	−0·9
"	..	"	"	25	8,332·42	+16·9	.....	0·41	−0·7
"	..	1912	Feb.	7	9,440·38	+21·2	.....	5·42	−1·7
Ottawa									
7950	Y	1916	Dec.	17	2,421,215·624	+19·6	1	6·51	+3·4
7989	"	1917	Jan.	12	1,241·632	+35·0	1	3·75	+6·4
7998	"	"	"	16	1,245·683	+ 7·5	1	7·80	+0·3
8013	"	"	"	22	1,251·771	+35·6	1	4·30	+8·3
8014	"	"	"	26	1,255·469	+12·7	1	8·00	+6·5
8027	"	"	Feb.	1	1,261·758	+29·0	1	4·70	+3·0
8044	"	"	"	11	1,271·658	+26·4	1	5·01	+1·4
8045	"	"	"	11	1,271·708	+27·0	1	5·06	+2·2
8049	"	"	"	12	1,272·619	+16·1	1	5·97	−3·9
8052	"	"	"	12	1,272·676	+17·5	1	6·03	−2·0
8061	"	"	"	15	1,275·762	+15·1	1	9·11	+6·1
8063	"	"	"	18	1,278·584	+26·9	1	2·34	−1·7
8064	"	"	"	18	1,278·658	+37·7	1	2·42	+9·0
8071	P	"	"	24	1,284·517	+ 5·3	1	8·28	−0·5
8073	Y	"	"	27	1,287·507	+28·9	1	1·68	+2·3
8082	"	"	Mar.	1	1,289·556	+33·8	1	3·73	+5·2
8098	"	"	"	6	1,294·562	+ 9·0	1	8·73	+2·2
8099	"	"	"	6	1,294·619	+10·4	1	8·79	+3·4
8100	"	"	"	6	1,294·674	+ 8·5	1	8·84	+0·8
8110	"	"	"	13	1,301·508	+14·1	1	6·09	−5·2
8111	"	"	"	13	1,301·561	+14·6	1	6·14	−4·2
8112	"	"	"	15	1,303·528	+ 5·0	1	8·11	−1·0
8116	C	"	"	16	1,304·641	+16·4	1	9·22	+6·4
8138	Y	"	April	8	1,327·528	+29·3	1	3·34	+0·2
8141	"	"	"	10	1,329·526	+18·9	1	5·34	−4·7
8142	"	"	"	10	1,329·580	+16·6	1	5·39	−6·4
Victoria									
778	Y	1918	Oct.	28	2,421,895·967	+23·5	1	5·97	+3·5
823	"	"	"	30	1,897·929	+ 7·7	½	7·93	+1·1
856	"	"	Nov.	4	1,902·937	+29·4	1	3·35	+0·3
900	"	"	"	20	1,918·894	+13·5	1	0·12	−1·5
901	"	"	"	20	1,918·901	+10·9	1	0·13	−4·1
926	"	"	"	22	1,920·937	+20·9	1	2·17	+2·7
927	"	"	"	22	1,920·951	+30·4	1	2·18	+2·2
988	P	"	"	26	1,924·902	+21·7	1	6·13	+2·9
1024	Y	"	Dec.	10	1,938·912	+23·9	1	0·96	+1·5
1040	"	"	"	14	1,942·925	+28·9	1	4·97	+3·8
1068	"	"	"	16	1,944·846	+10·6	1	6·90	−2·7
1098	"	"	"	20	1,948·822	+25·7	1	1·28	+1·1
1099	"	"	"	20	1,948·828	+24·7	1	1·29	+0·1
1148	P	"	"	29	1,957·834	+20·2	1	0·70	−0·1
1149	"	"	"	29	1,957·843	+19·3	1	0·71	−1·2
1186	"	"	"	31	1,959·785	.....	0	.....	.....

TABLE OF OBSERVATIONS—*Continued.*

Plate	Observer	Date			Julian Day	Velocity	Wt.	Phase	O-C
1203	Y	1919	Jan.	6	2,421,965·822	+ 4·0	1	8·69	−2·5
1204	"	"	"	6	1,965·829	+ 5·4	1	8·70	−1·1
1270	"	"	"	10	1,969·803	+27·2	1	3·08	−2·0
1271	"	"	"	10	1,969·811	+30·0	1	3·09	+0·8
1272	"	"	"	10	1,969·819	+26·1	1	3·10	−3·1
1295	P	"	"	19	1,978·782	+26·4	1	2·47	−2·3
1306	Y	"	"	29	1,988·719	+26·6	1	2·82	−2·5
1307	"	"	"	29	1,988·728	+25·8	1	2·83	−3·3
1327	P	"	"	30	1,989·787	+25·2	1	3·89	−3·1
1328	"	"	"	30	1,989·795	+24·6	1	3·90	−3·7
1342	Y	"	"	31	1,990·741	+27·4	1	4·84	+1·8
1343	"	"	"	31	1,990·749	+27·9	1	4·85	+2·3
1369	P	"	Feb.	1	1,991·834	+21·1	1	5·93	+0·9
1381	"	"	"	2	1,992·714	+12·3	1	6·81	−1·7
1382	"	"	"	2	1,992·719	+12·8	1	6·82	−1·2
1391	"	"	"	4	1,994·723	+ 9·2	1	8·82	+2·1
1395	Y	"	"	5	1,995·584	+13·3	1	0·09	−1·3
1396	"	"	"	5	1,995·592	+10·3	1	0·10	−4·3
1397	"	"	"	5	1,995·601	+12·0	1	0·11	−2·7
1407	"	"	"	5	1,995·800	+13·7	1	0·31	−3·1
1408	"	"	"	5	1,995·811	+12·9	1	0·32	−3·9
1409	"	"	"	5	1,995·820	+13·3	1	0·33	−3·5
1427	"	"	"	11	2,001·772	+17·4	1	6·28	−0·5
1428	"	"	"	11	2,001·778	+17·4	1	6·29	−0·5
1448	P	"	"	16	2,006·735	+25·0	1	1·66	−1·5
1449	"	"	"	16	2,006·742	+26·5	1	1·66	0·0
1477	"	"	"	21	2,011·695	+14·4	1	6·61	−1·0
1491	"	"	"	23	2,013·749	+ 9·5	1	8·67	+3·0
1492	"	"	"	23	2,013·756	+ 9·7	1	8·68	+3·2
1516	"	"	Mar.	8	2,026·651	+28·2	1	2·39	−0·5
1559	Y	"	"	19	2,037·626	+25·4	1	3·78	−2·8
1583	P	"	"	20	2,038·675	+26·8	1	4·82	+1·2
1603	Y	"	"	21	2,039·638	+23·3	1	5·79	+2·3
1642	P	"	"	23	2,041·722	+ 6·2	1	7·87	−0·5
1643	"	"	"	23	2,041·727	+ 7·8	1	7·88	+1·0
1662	Y	"	"	24	2,042·625	+ 2·1	1	8·77	−4·7

Both the Ottawa and Victoria measures were used in forming the following normal places.

	Phase from J. D. 2,421,890	Velocity	Wt.	Preliminary O-C	Final O-C	Preliminary pvv	Final pvv
1	9·468	+12·3	1·33	−0·60	− ·12	·48	·01
2	0·790	+21·1	0·50	−0·05	·00	·00	·00
3	1·472	+25·5	0·67	−0·06	− ·09	·00	·01
4	2·317	+29·8	1·60	+1·14	+1·26	1·30	1·59
5	3·163	+28·3	1·16	−1·31	−0·80	2·00	·92
6	3·884	+27·4	0·83	−1·63	−0·99	2·22	·84
7	4·980	+25·9	1·00	0·00	+0·86	·00	·74
8	6·037	+20·4	1·00	+0·20	+0·94	·04	·88
9	6·393	+16·4	0·50	−1·30	−0·68	·85	·23
10	6·843	+11·9	0·50	−2·32	−1·88	2·69	1·76
11	7·968	+ 7·3	0·67	+0·60	+0·83	·24	·46
12	8·722	+ 6·5	1·50	−0·66	−0·41	·66	·00

00925710

From these normal places the preliminary elements were determined graphically.

$$P = 9{\cdot}590 \text{ days}$$
$$T = \text{J. D. } 2{,}421{,}898{\cdot}559$$
$$e = 0{\cdot}20$$
$$\omega = 195^\circ$$
$$K = 11{\cdot}75 \text{ km.}$$
$$\gamma = +20{\cdot}13 \text{ km.}$$
$$c = +17{\cdot}85 \text{ km.}$$

The residuals which the normal places leave when represented by the elements are shown under the heading O–C preliminary in the table of normal places. Observation equations were formed for these residuals and the elements adjusted by the method of least squares. The steps in the solution are recorded below.

OBSERVATION EQUATIONS

							Wt.
1	1·000x	− ·615y	+ ·577z	+ ·959u	+1·154v	− ·600 = 0	1·33
2	1·000	+ ·087	+1·050	+1·012	+ ·952	− ·050	0·50
3	1·000	+ ·462	+ ·388	+ ·808	+ ·631	− ·060	0·67
4	1·000	+ ·726	− ·498	+ ·446	+ ·280	+1·140	1·00
5	1·000	+ ·807	− ·962	+ ·059	+ ·005	−1·310	1·16
6	1·000	+ ·758	− ·935	− ·259	− ·199	−1·630	0·83
7	1·000	+ ·491	− ·232	− ·678	− ·503	0·000	1·00
8	1·000	+ ·006	+ ·781	− ·928	− ·813	+0·200	1·00
9	1·000	− ·207	+1·004	− ·948	− ·904	−1·300	0·50
10	1·000	− ·503	+1·025	− ·899	− ·972	−2·320	0·50
11	1·000	−1·143	− ·578	− ·262	− ·428	+ ·600	0·67
12	1·000	−1·104	− ·812	+ ·464	+ ·590	− ·660	1·50

where $x = d\gamma$
$y = dK$
$z = Kde$
$u = Kd\omega$
$v = \dfrac{-K\mu}{(1-e^2)^{\frac{1}{2}}}\, dT$

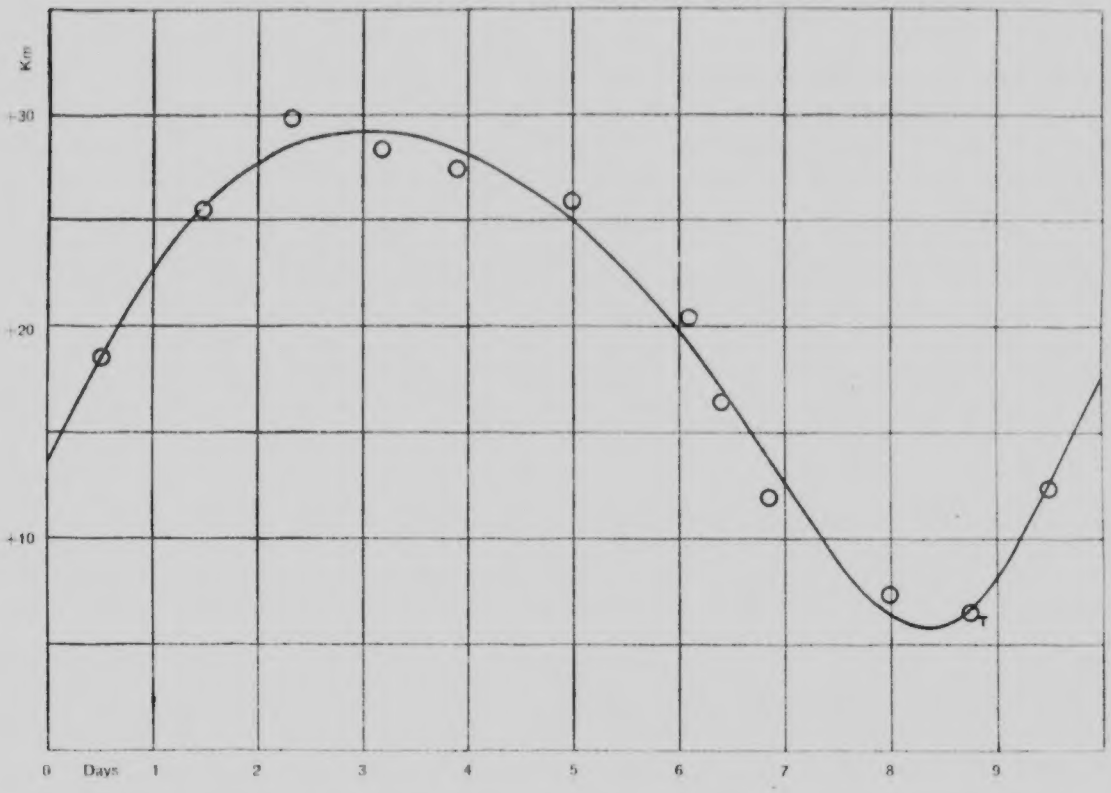
NORMAL EQUATIONS

10·667x	− ·446y	− ·896z	+ ·644u	+ ·902v	−4·811 = 0
	+5·504	− ·851	− ·861	−1·193	+ ·392 = 0
		+6·034	− ·583	− ·473	+ ·555 = 0
			+4·978	+4·903	+ ·855 = 0
				+5·045	+ ·407 = 0

whence $x = -0{\cdot}4164$ or $d\gamma = -0{\cdot}42$ km.
$y = -0{\cdot}0082$ $dK = -0{\cdot}01$ km.
$z = +0{\cdot}0762$ $de = +{\cdot}0065$
$u = +1{\cdot}6985$ $d\omega = +8^\circ{\cdot}28$
$v = -1{\cdot}4963$ $dT = +0{\cdot}182$ day.

The final elements are

P	= 9·590 days	
e	= 0·2065	± ·0344
K	= 11·74 km.	± ·33 km.
γ	= +19·71 km.	± ·22 km.
ω	= 203°28	±6°80
T	= J. D. 2,421,898·741	± ·196 day
a sin i	= 1,510,000 km.	
$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$	= ·0015 ⊙	



These elements are suggestive of the spectroscopic elements for the cepheid variables. The period is the shortest yet found for a star of G type if we exclude the Cepheids but is quite normal for a star of that class. The range is small and the eccentricity high for a binary of such short period. The orbit is minute. The observations do not fit the curve as well as the character of the spectrum would lead one to expect, the probable error of a single plate being, for Victoria, 1·61 km., for Ottawa, 3·00 km. All these characteristics belong also to the Cepheids. On the other hand the star has not been observed to vary and accepting Adams' value for the parallax and luminosity, π = 0·052, L = 6·92 the absolute magnitude is +2·82. According to Shapley's curve in the Astronomical Society of the Pacific, February, 1918, for the Cepheid variables, a star of this period and apparent

magnitude should have an absolute magnitude of −3·0. The writer suspected the spectrum to vary somewhat from F8 to G5 or K, but on making estimates of the relative intensities of the pairs of lines used by the Mount Wilson Observatory for the determination of type, this apparent variation vanished and it was further noticed that the altered appearance of the spectrum depended on the exposure of the plates. Those plates that were normal were all alike but the over exposed plates, of which there were several, had the absorption lines so veiled over as to make the spectrum at first glance resemble an earlier type than it really was.

The tentative conclusion one would be led back to is, that the star is probably not a cepheid variable but that it is a G type binary with the shortest period yet found and that the discrepancies in the earlier observations render it advisable to investigate the star further when higher dispersion is available.

Dominion Astrophysical Observatory,
Victoria, B.C.
July, 1919.